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(54) **MINIMIZED COLOR SHIFT LIGHTING ARRANGEMENT DURING DIMMING**

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H05B 33/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H05B 33/0827*** (2013.01); ***H05B 37/02*** (2013.01); *H05B 37/0272* (2013.01)

(58) **Field of Classification Search**
CPC H05B 37/02
See application file for complete search history.

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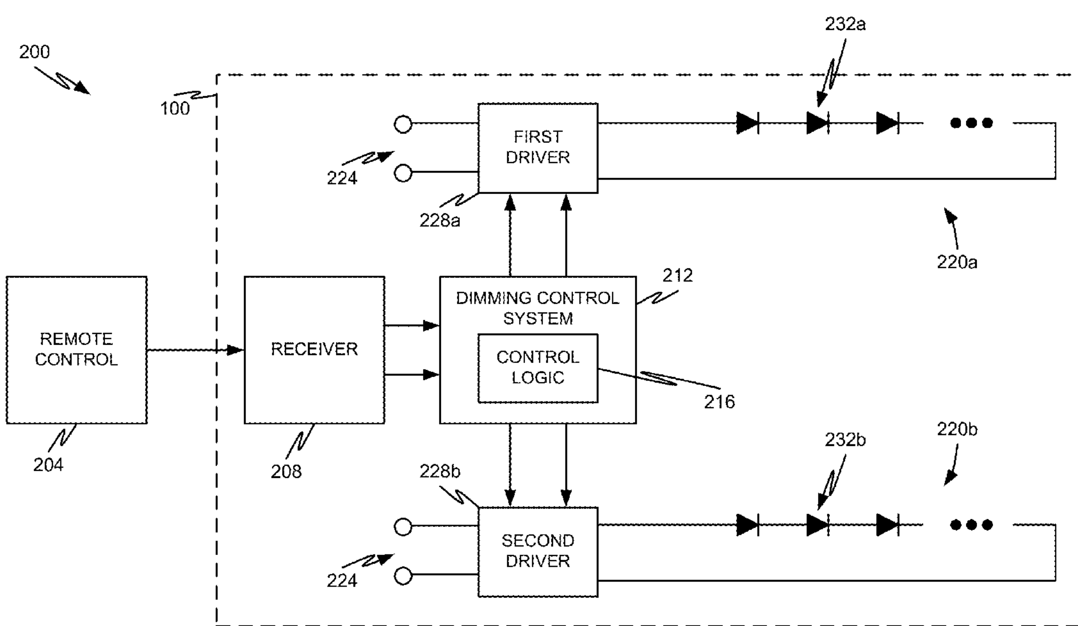
(57) **ABSTRACT**

An illumination device, system, and method are disclosed. The illumination system includes a first set of light sources and a second set of light sources, driven by a first driver and second driver, respectively. The system further includes a dimming control system that implemented dimming control logic. The dimming control logic coordinates the operation of the first and second drivers such that the first and second sets of light sources are activated and deactivated so as to achieve substantially constant color temperature during dimming operations.

20 Claims, 7 Drawing Sheets



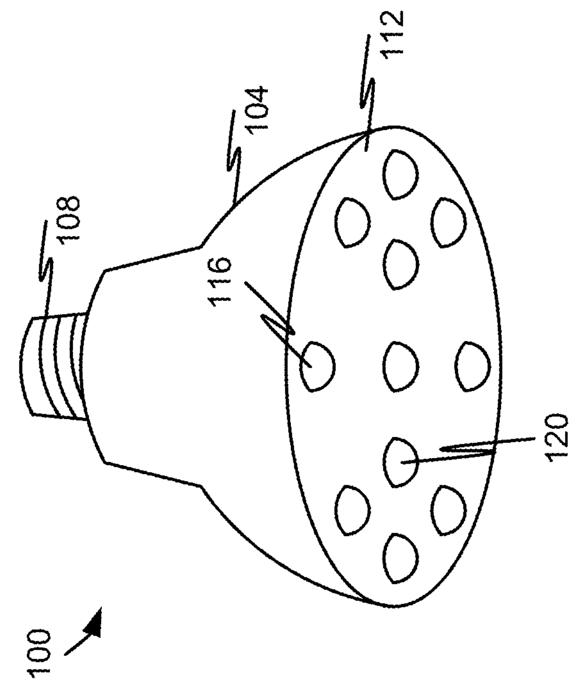


FIG. 1

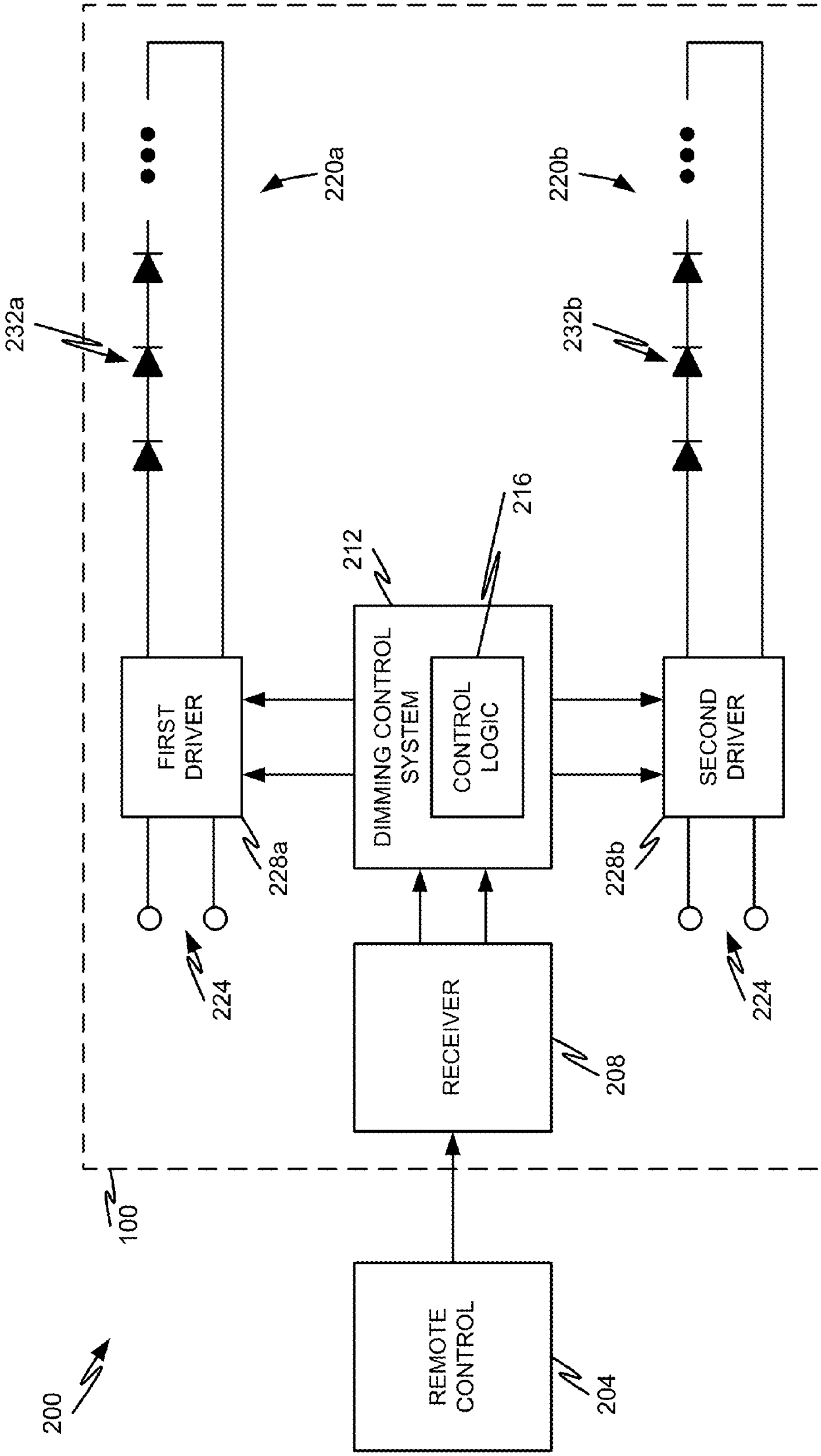

200
REMOTE CONTROL
204
100
RECEIVER
208
DIMMING CONTROL SYSTEM
CONTROL LOGIC
212
216
FIRST DRIVER
228a
SECOND DRIVER
228b
224
224
220a
220b
232a
232b

FIG. 2

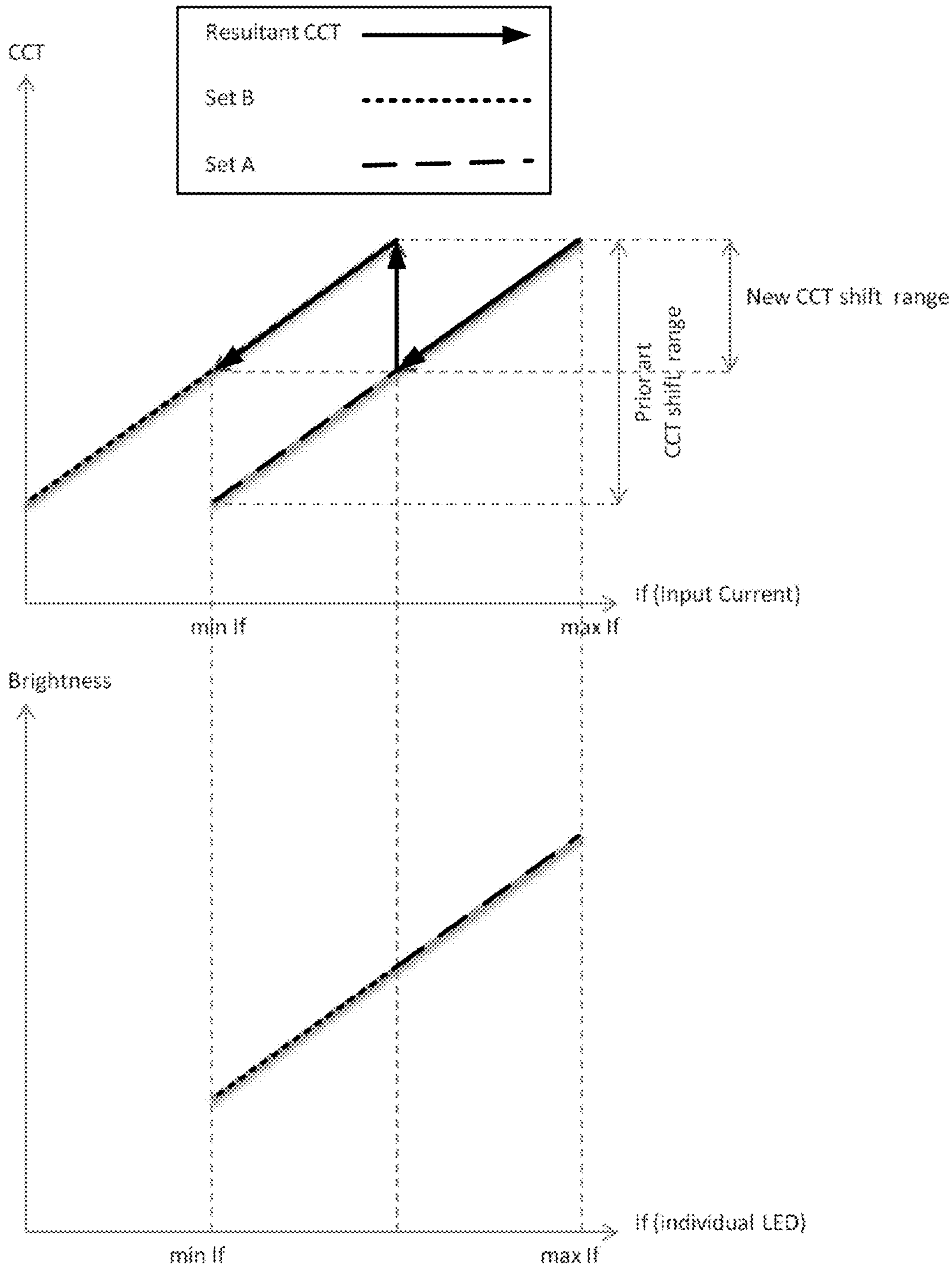

Resultant CCT
Set B
Set A
CCT
New CCT shift range
Prior art
CCT shift range
If (Input Current)
min If
max If
Brightness
If (individual LED)
min If
max If

FIG. 3

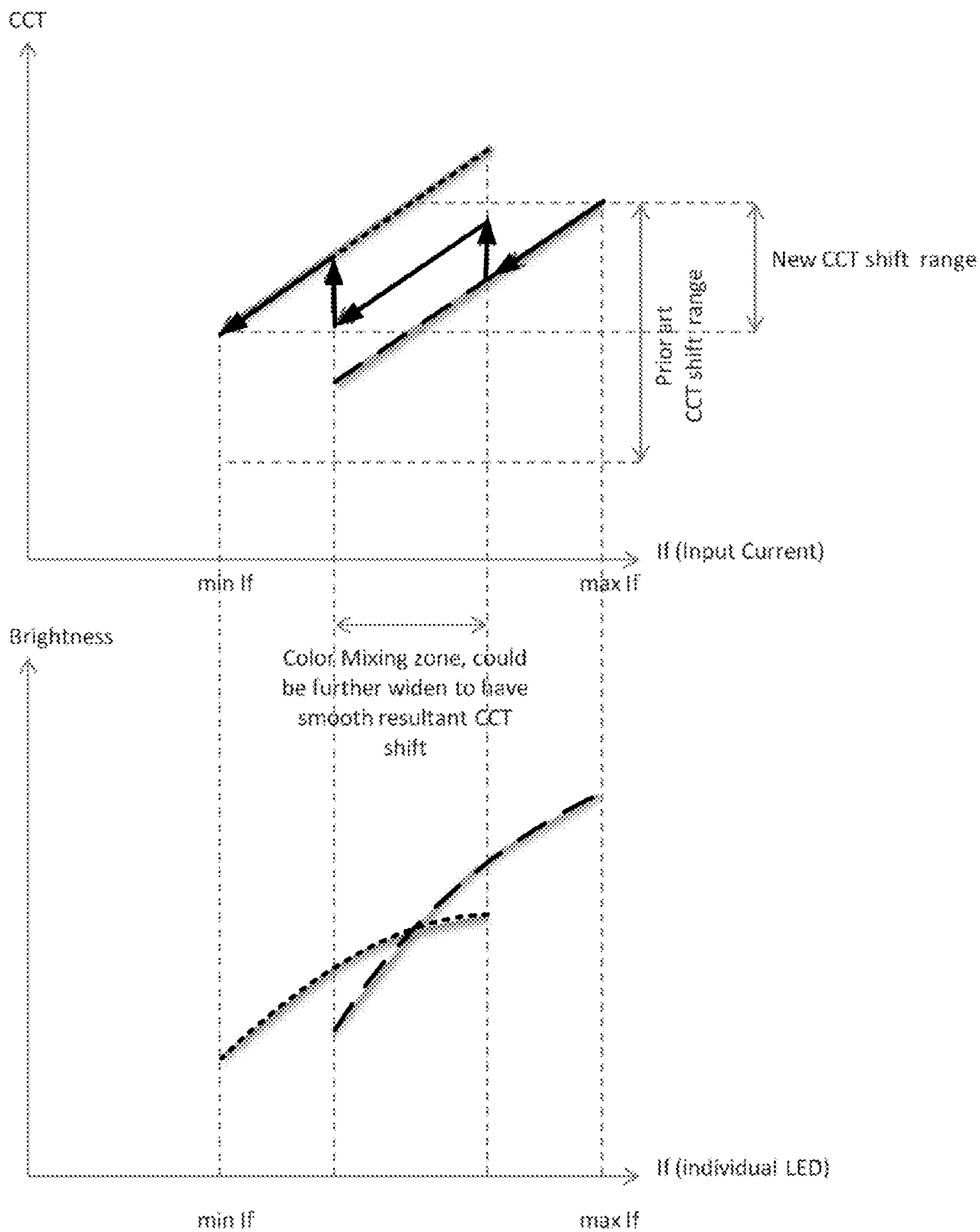

CCT
New CCT shift range
Prior art
CCT shift range
If (Input Current)
min If
max If
Brightness
Color Mixing zone, could be further widen to have smooth resultant CCT shift
If (individual LED)
min If
max If

FIG. 4

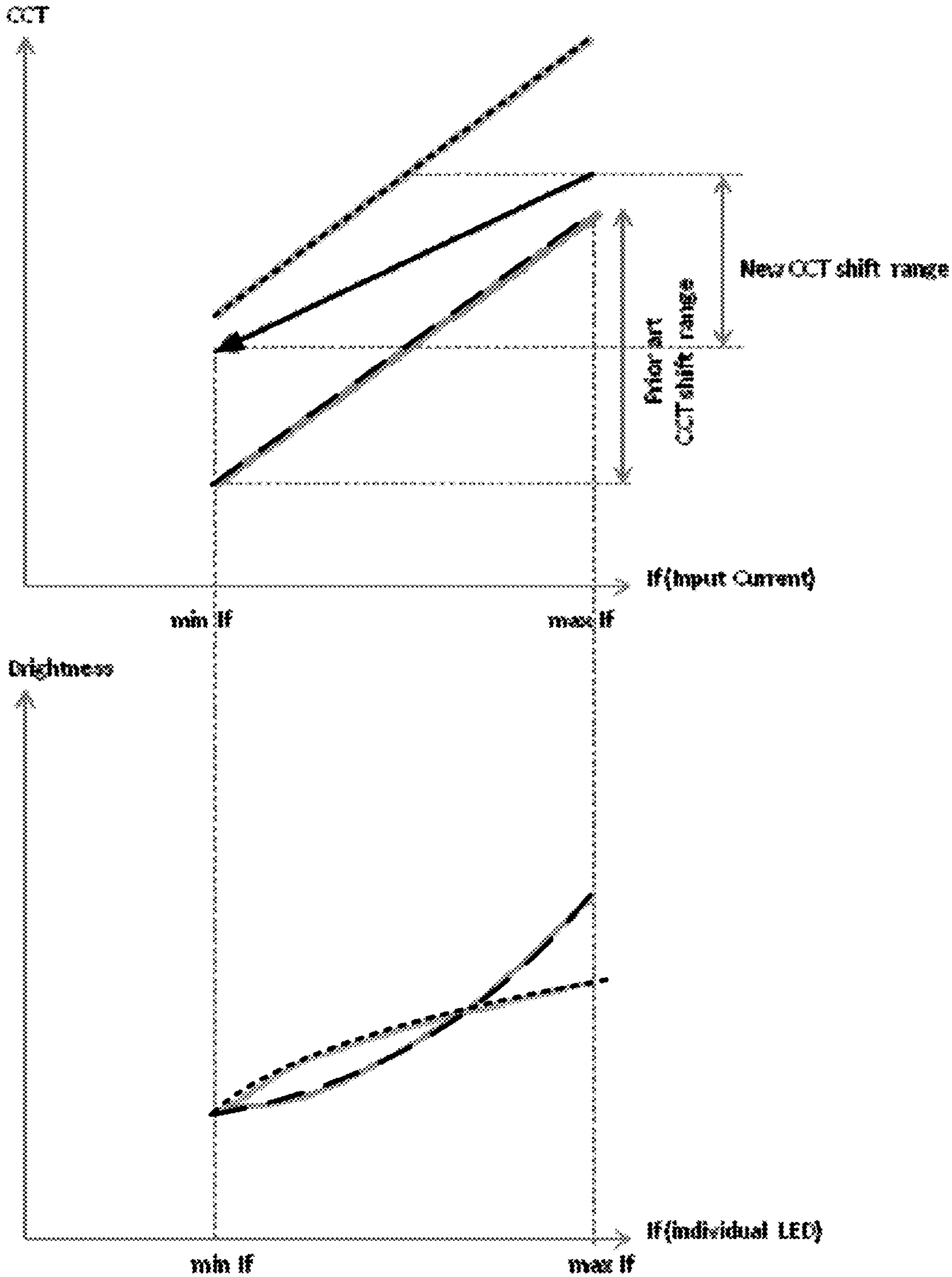

CCT
New CCT shift range
Prior art
CCT shift range
If(Input Current)
min If
max If
Brightness
If(individual LED)
min If
max If

FIG. 5

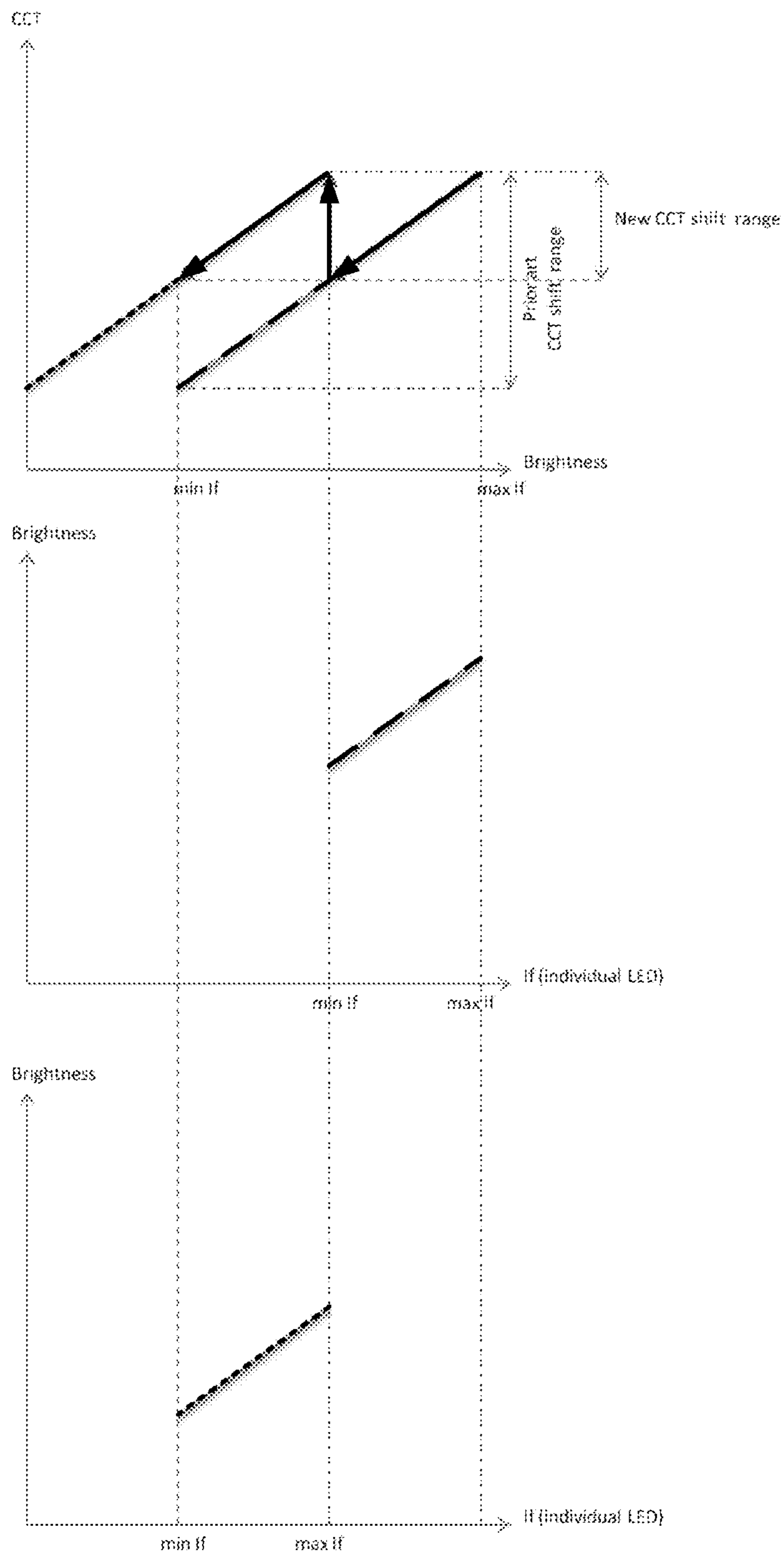

CCT
New CCT shift range
Prior art
CCT shift range
Brightness
min If
max If
Brightness
If (individual LED)
min If
max If
Brightness
If (individual LED)
min If
max If

FIG. 6

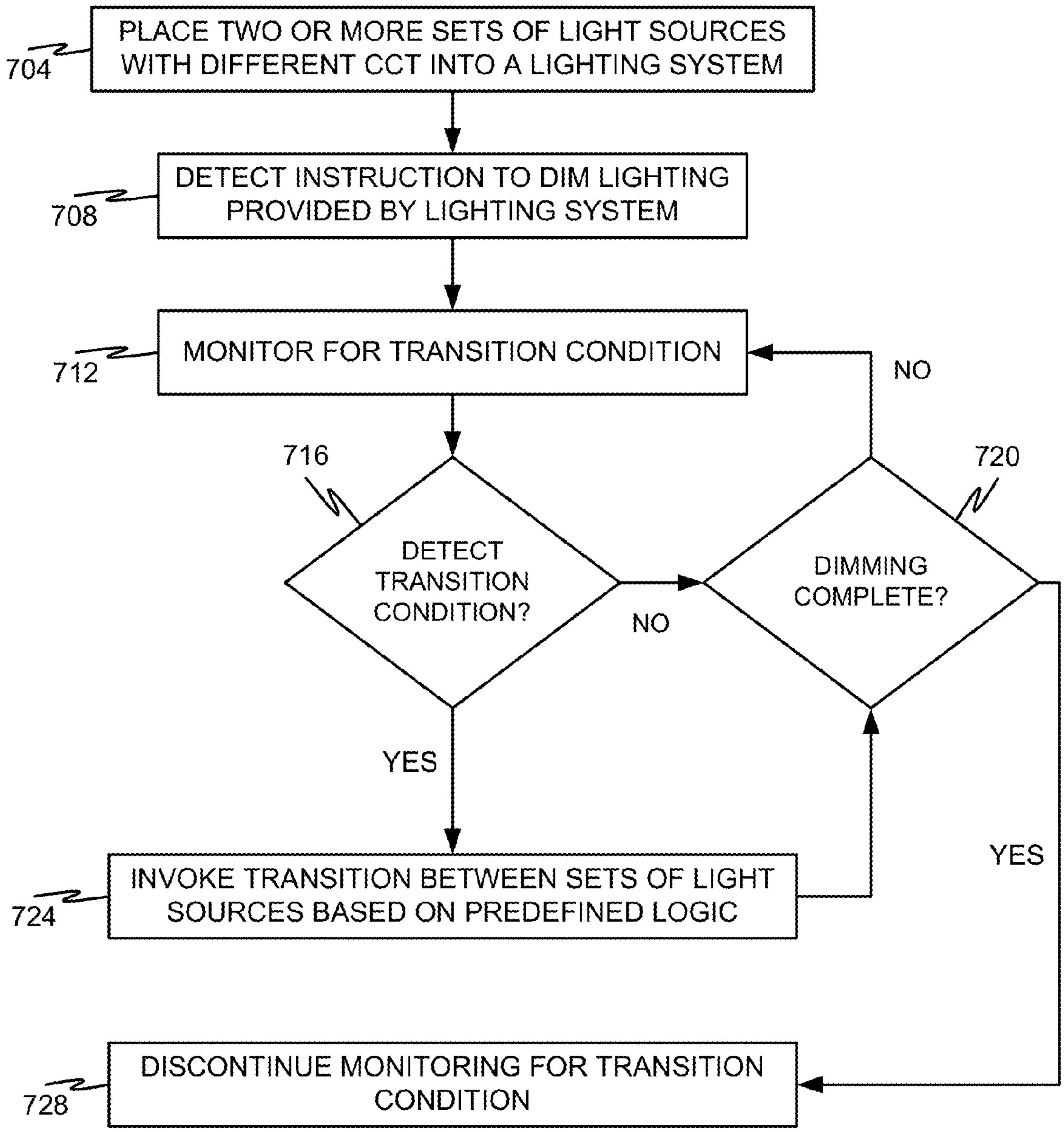

PLACE TWO OR MORE SETS OF LIGHT SOURCES WITH DIFFERENT CCT INTO A LIGHTING SYSTEM
704
DETECT INSTRUCTION TO DIM LIGHTING PROVIDED BY LIGHTING SYSTEM
708
MONITOR FOR TRANSITION CONDITION
712
NO
716
DETECT TRANSITION CONDITION?
NO
720
DIMMING COMPLETE?
YES
YES
INVOKE TRANSITION BETWEEN SETS OF LIGHT SOURCES BASED ON PREDEFINED LOGIC
724
DISCONTINUE MONITORING FOR TRANSITION CONDITION
728

FIG. 7

MINIMIZED COLOR SHIFT LIGHTING ARRANGEMENT DURING DIMMING

FIELD OF THE DISCLOSURE

The present disclosure is generally directed toward light emitting devices and particularly toward dimmable light emitting diodes.

BACKGROUND

Light Emitting Diodes (LEDs) have many advantages over conventional light sources, such as incandescent, halogen and fluorescent lamps. These advantages include longer operating life, lower power consumption, and smaller size. Consequently, conventional light sources are increasingly being replaced with LEDs in traditional lighting applications. As an example, LEDs are currently being used in flashlights, camera flashes, traffic signal lights, automotive taillights and display devices. LEDs have also gained favor in residential, industrial, and retail lighting applications.

Color temperature is a simplified way to characterize the spectral properties of a light source. While in reality the color of light is determined by how much each point on the spectral curve contributes to its output, the result can still be summarized on a linear scale. This value is useful, for example, for specifying the right light source types in architectural lighting design. Note, however, that light sources of the same color (metamers) can vary widely in the quality of light emitted. One may have a continuous spectrum, while the other just emits light in a few narrow bands of the spectrum. A useful way to determine the quality of a light source is its color rendering index. The Correlated Color Temperature (CCT) is a specification of the color appearance of the light emitted by a light source, relating its color to the color of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K).

Low color temperature implies warmer (more yellow/red) light while high color temperature implies a colder (more blue) light. Daylight has a rather low color temperature near dawn, and a higher one during the day.

Existing LED lighting exhibits color shift during dimming. Said another way, when the amount of current provided to an LED or group of LEDs is reduced from one current value to another current value, the brightness of the LED will change, but so too will the color produced by the LED. When the current provided to an LED is reduced from the maximum input current to the minimum allowable input current, the color of the LED could shift by as much as 300K CCT, which is generally noticeable by users. Because of this color-shifting phenomenon, it has been more difficult to provide a suitable LED alternative for dimmable lights.

SUMMARY

It is, therefore, one aspect of the present disclosure to provide a lighting arrangement that overcomes the above-noted shortcomings of LED-based lights. Specifically, embodiments of the present disclosure reduce LED color shifting at least by half as much as compared to the dimmable lighting arrangements of the prior art. This reduction in color shifting during dimming increases the desirability of LED alternatives in dimmable lights.

In accordance with at least some embodiments, an illumination device or system is provided that is capable of exhibiting a reduced fluctuation in CCT by employing at least two sets of different light sources during dimming. The second set of light sources, in some embodiments, will take over an active role for the first set after it is determined that the illumination device or system (e.g., all light sources) has been dimmed below a predetermined dimming threshold. In some embodiments, the illumination device or system may include a first driver configured to drive the first set of light sources and a second driver configured to drive the second set of light sources. Both the first and second driver may be connected to the same or different power supplies and may be connected to and controlled by a common dimming control system. The dimming control system may include control logic that is configured to control the drivers for each set of light sources, thereby coordinating the dimming process and maintaining a generally constant color temperature during dimming operations.

In some embodiments, a dimming method is provided that generally includes providing at least two sets of light sources with different CCTs into an illumination device or system. In some embodiments, the second set of light sources has a relatively higher CCT as compared to the first set of light sources when the light sources are driven at the same electrical current.

In some embodiments, the method continues when, at a maximum input current, the first set of light sources are activated (e.g., illuminated). As the current provided to the first set of light sources is reduced, the CCT of the first set of light sources also begins to reduce. At a predetermined point of dimming down (e.g., a transition condition), the dimming control system will detect the need to transition between the first set of light sources and the second set of light sources. Once a transition condition has been satisfied, the second set of light sources can be activated (e.g., illuminated) to help take over for or supplement the first set of light sources. As the second set of light sources is activated, the overall CCT of the illumination device or system will be pull up instead of continuing to drop.

It should be appreciated that the transition condition may comprise more than a single predetermined input current to the first set of light sources. Instead, the transition condition may correspond to a set of transition conditions or a dimming range, through which the second set of light sources is gradually allowed to take over for or supplement the first set of light sources. As dimming continues through the dimming range, the second set of light sources will begin to dominate the first set of light sources until the first set of light sources have been deactivated. Once the first set of light sources has been deactivated, the transition condition (or dimming range) may be considered completed and the remainder of dimming will be achieved via the second set of light sources only (e.g., the first set of light sources will already be deactivated).

In other embodiments, the first set of light sources may not totally switch off and be completely replaced by the second set of light sources. Rather, the first set of light sources may be dimmed down at a faster rate while the second set of light sources begin to lighten up at a predetermined rate. This soft transition will further help to reduce the color fluctuation due to color mixing.

In other embodiments, the first and second set of light sources may be activated at the same time, but the ratio of brightness for each set of light sources may vary. This varied brightness ratio may help to create a smooth CCT and brightness transition.

In yet other embodiments, the second set of light sources can have substantially the same or a slight lower CCT as compared to the first set of light sources, but the same

desired dimming effects can be achieved when the number of light sources in the second set of light sources is less than the number of light sources in the first set of light sources (e.g., the first set of light sources has substantially more light sources than the second set of light sources). In such a configuration, when the second set of light sources take over for the first set of light sources, they may be initiated in a maximum current, but since the number of light sources in the second set of light sources is smaller than the number of light sources in the first set of light sources, the overall brightness is lower; this could enable a tolerable brightness continuity.

The present disclosure will be further understood from the drawings and the following detailed description. Although this description sets forth specific details, it is understood that certain embodiments of the invention may be practiced without these specific details. It is also understood that in some instances, well-known circuits, components and techniques have not been shown in detail in order to avoid obscuring the understanding of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is described in conjunction with the appended figures:

FIG. **1** is an isometric view of a dimmable illumination device in accordance with embodiments of the present disclosure;

FIG. **2** is a block diagram of an illumination system in accordance with embodiments of the present disclosure;

FIG. **3** is a set of charts depicting CCT and brightness as a function of input current for a first lighting arrangement in accordance with embodiments of the present disclosure;

FIG. **4** is a set of charts depicting CCT and brightness as a function of input current for a second lighting arrangement in accordance with embodiments of the present disclosure;

FIG. **5** is a set of charts depicting CCT and brightness as a function of input current for a third lighting arrangement in accordance with embodiments of the present disclosure;

FIG. **6** is a set of charts depicting CCT and brightness as a function of input current for a fourth lighting arrangement in accordance with embodiments of the present disclosure; and

FIG. **7** is a flow chart depicting a dimming method in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

The ensuing description provides embodiments only, and is not intended to limit the scope, applicability, or configuration of the claims. Rather, the ensuing description will provide those skilled in the art with an enabling description for implementing the described embodiments. It being understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the appended claims.

With reference now to FIG. **1**, an illustrative illumination device **100** is depicted in accordance with at least some embodiments of the present disclosure. The depicted illumination device **100** corresponds to an LED-based lamp, having a flood light configuration. It should be appreciated, however, that embodiments of the present disclosure are not limited to the specific configuration of illumination device **100** depicted. Rather, embodiments of the present disclosure may be applied to any type of illumination device or collection of illumination devices such as tube lighting, flood lighting, track lighting, chandeliers, fan lights, pendant lighting, recessed or can lighting, etc.

The depicted illumination device **100** comprises a body **104**, an interconnect **108**, a face **112**, a first type of light source **116**, and a second type of light source **120**. The body **104** may comprise a heat sink component in addition to housing other parts of the illumination device **100**. For instance, the body **104** may house the circuitry used to drive the light sources **116**, **120** as wells as the components that condition the power supplied to the light sources **116**, **120**. More specifically, the body **104** may comprise one or more Printed Circuit Boards (PCBs) onto which the light sources **116**, **120** can be mounted as well as the electrical components used to operate the light sources **116**, **120**. In addition, the body **104** may be constructed of a thermally-conductive material (e.g., aluminum or metal alloys) to help dissipate heat generated by the light sources **116**, **120** during operation.

One end of the body **104** may be connected to an interconnect **108**. The interconnect **108** may provide the illumination device **100** with the ability to mechanically and electrically join with a lighting fixture or outlet. In some embodiments, the interconnect **108** may comprise a male threaded metal portion that interfaces with male threaded female portion of a lighting fixture or outlet. Current provided to the illumination device **100** may initially pass from wiring in a wall, for example, to the lighting fixture or outlet where it is received at the interconnect **108**. The interconnect **108** may be electrically connected to the drivers contained in the body **104** which ultimately condition and provide current to the light sources **116**, **120**.

The face **112** of the body **104** may correspond to a planar or non-planar surface where the light sources **116**, **120** are exposed. In some embodiments, the face **112** may directly expose the light sources **116**, **120**. In some embodiments, the light sources **116**, **120** may be mounted to the face and then shielded with a transparent or translucent cover. The cover, as an example, may comprise one or more light diffusing elements that help soften the light emitted by the light sources **116**, **120** prior to exiting the illumination device **100**. Other embodiments may simply comprise the light sources **116**, **120** mounted in an exposed fashion on the face **112**.

The illustrative illumination device **100** comprises a first type of light source **116** and a second type of light source **120** and multiple of each type of light source are depicted. It should be appreciated that embodiments of the present disclosure are not so limited. Instead, embodiments of the present disclosure contemplate an illumination device **100** that comprises a single first type of light source **116** and a single second type of light source **120** in a basic configuration. More elaborate configurations are also contemplated. As a non-limiting example, an illumination device **100** may have a first set of light sources of the first type and a second set of light sources of the second type. The number of light sources in the first set of light sources (e.g., the number of light sources **116**) may be greater than, less than, or equal to the number of light sources in the second set of light sources (e.g., the number of light sources **120**). As a more specific non-limiting example, the number of light sources in the second set of light sources may be substantially less (e.g., 1.25, 1.5, 2, 3, or more times less) than the number of light sources in the first set of light sources. Further still, although only two types of light sources **116**, **120** are depicted, it should be appreciated that embodiments of the present disclosure contemplate an illumination device **100** and system that comprises two, three, four, five, six, seven, or more different types of light sources. Each of the different types of light sources may be separated into different sets of light sources where each type is driven by a different driver or some different types of light sources may be included in a common set of light sources such that they are driven by the same driver.

The light sources **116**, **120** may be distributed across the face **112** in any configuration. As an example, the light sources **116**, **120** may be randomly or evenly distributed across the face **112** to provide an even light output. Alternatively, some of the first type of light sources **116** may be clustered while some of the second type of light sources **120** may be clustered. As another example, the light sources **116**, **120** may be organized in alternating concentric rings (e.g., inner ring of first type of light sources **116**, second inner ring of second type of light sources **120**, third inner ring of first type of light sources **116**, etc.).

Any type of known light source may be used for the light sources **116**, **120**. As some non-limiting examples, the light source(s) **116**, **120** may correspond to an LED, an array of LEDs, a laser diode, or the like. In some embodiments, a plurality of LEDs may be configured to emit light when a voltage difference is applied across the anode and cathode of the LEDs (e.g., current is provided to the LEDs). In some embodiments, the light source(s) **116**, **120** may comprise a thru-hole mount LED and/or surface mount LED. Another type of light source **116**, **120** that may be employed in accordance with embodiments of the present disclosure is an Organic LED (OLED) sheet or film.

In some embodiments, the first type of light source **116** may have at least one different characteristic or property as compared to the second type of light source **120**. As a non-limiting example, the first type of light source **116** may be configured to emit light of a first predetermined wavelength or color whereas the second type of light source **120** may be configured to emit light of a second predetermined wavelength or color that is different from the first predetermined wavelength or color. As another non-limiting example, the first type of light source **116** may comprise a first type of encapsulant while the second type of light source **120** may comprise a second type of encapsulant. More specifically, the first type of light source **116** may be encapsulated in a first type of encapsulant (e.g., having a first type of phosphor, epoxy, silicone, combinations thereof, etc.) while the second type of light source **120** may be encapsulated in a second type of encapsulant (e.g., having a second type of phosphor, epoxy, silicone, combinations thereof, etc.). In yet another non-limiting example, the first light source **116** comprises a lower CCT as compared to the second light source **120** when both light sources are driven at substantially the same current. Other variations between the first type of light source **116** and second type of light source **120** are also contemplated.

With reference now to FIG. **2**, an illustrative illumination system **200** will be described in accordance with at least some embodiments of the present disclosure. The illumination system **200** is depicted as incorporating a single illumination device **100**; however, it should be appreciated that an illumination system **200** may comprise multiple illumination devices **100** without departing from the scope of the present disclosure.

The illumination system **200** may comprise a remote control **204** adapted to adjust and/or control the operation of the illumination device **100**. Specifically, the remote control **204** may be operated by a user that wishes to adjust or control the brightness of the illumination device **100**. In particular, the remote control **204** may enable a user to remotely turn on, turn off, dim, or brighten the illumination device **100**. As used herein, the term "dimming" will be used to refer to both the act of decreasing the amount of current provided to the illumination device **100** as well as the act of increasing the amount of current provided to the illumination device **100**. In other words, a user may be dimming the illumination device **100** by dictating the amount of current provided to the illumination device **100** to be less than the maximum allowable current, regardless of whether or not the provided current is being increased or decreased. The control exerted over the amount of current provided to the illumination device **100** may be facilitated by the remote control **204**, which may be portable, handheld, or wall-mounted.

A wall-mounted remote control **204** will generally communicate with the receiver **208** via a wired connection. A portable or handheld remote control **204** will generally communication with the receiver **208** via a wireless connection. More specifically, the remote control **204** and receiver **208** may communicate via one or more of Radio Frequency (RF) communications, Infrared (IR) communications, Bluetooth, Ultrahigh Frequency (UHF) communications, WiFi (e.g., in accordance with one or more IEEE standards such as IEEE 802.11x), ZigBee, Near Field Communications (NFC), acoustically, etc.

In some embodiments, the remote control **204** communicates with the receiver **208** to provide instructions for controlling the light output by the illumination device **100**. Specifically, the remote control **204** may provide a user with options to dim, brighten, turn on, and/or turn off the illumination device **100** or multiple illumination devices **100** (e.g., multiple illumination devices within a common room, building, area, etc.). The user input received at the remote control **204** is communicated to the receiver **208** as described above. The receiver **208** may translated the instructions received from the remote control **204** into instructions that can be understood and/or interpreted by a dimming control system **212**.

In accordance with at least some embodiments, the illumination system **200** comprises a dimming control system **212** that can be used to control the dimming operations of one or more illumination devices **100**. More specifically, the dimming control system **212** may comprise control logic **216** that converts the instructions received at the receiver **208** into light control operations. The light control operations may then be carried out with the dimming control system **212** instructing one or more drivers **228*a***, **228*b*** to adjust the amount of current provided to their respective circuitry **220*a***, **220*b***.

In some embodiments, the control logic **216** may be provided as an Application Specific Integrated Circuit (ASIC), firmware, a Programmable Logic Controller (PLC), or combinations thereof. In some embodiments, the control logic **216** may be implemented as instructions stored in memory and executed by a microprocessor or set of microprocessors. In some embodiments, the control logic **216** may comprise the logic to determine whether one or both of the light sources **232*a***, **232*b*** should be turned on, turned off, dimmed, or brightened. More specifically, the control logic **216** may be configured to determine if the user is providing an instruction to dim the illumination device **100** and, if so, further determine how much the illumination device **100** should be dimmed (e.g., what percentage of the maximum light output is desired). Based on the amount of dimming that is being requested by the user of the remote control **204**, the control logic **216** may be capable of selectively controlling whether one or both circuits **220*a***, **220*b*** should receive current from their respective drivers **228*a***, **228*b***.

In some embodiments, the first circuit **220**a may comprise a first set of light sources **232**a, which may include one or more of the first type of light sources **116**. Similarly, the second circuit **220**b may comprise a second set of light sources **232**b, which may include one or more of the second type of light sources **120**. As a non-limiting example, the first type of light sources **116** in the first set of light sources **232**a may be connected in series to form the first circuit **220**a while the second type of light sources **120** in the second set of light sources **232**b may be connected in series to form the second circuit **220**b.

The first circuit **220**a may have its current controlled or driven by the first driver **228**a whereas the second circuit **220**b may have its current controlled or driven by the second driver **228**b. The drivers **228**a, **228**b may each be connected to a power input **224**, which may be a common power input or different power inputs. As an example, a single power input **224** (A/C or D/C) may be collected from the interconnect **108** and provided to both drivers **228**a, **228**b. Each driver **228**a, **228**b may then adjust the amount of current passed along to their respective circuit **220**a, **220**b based on the instructions received from the dimming control system **212**. Although not depicted, the circuits **220**a, **220**b may comprise other circuit components such as one or more resistors, capacitors, inductors, diodes, transistors, or the like.

Furthermore, although certain components are depicted in FIG. **2** as being incorporated in the illumination device **100**, it should be appreciated that one, some, or many components depicted as being incorporated within the illumination device **100** may actually be physically separated from the illumination device **100**. For instance, a receiver **208** and/or dimming control system **212** may be integrated into the illumination device **100** (e.g., within the housing **104**) as depicted. Alternatively, the receiver **208** and/or dimming control system **212** may be separate from the illumination device **100** and may be provided with a lighting fixture or as some other discrete component. Further still, a single dimming control system **212** and control logic **216** may be used to control the brightness of a plurality of illumination devices **100** by providing a common driver input to the drivers of each illumination device **100**. In other words, the configuration of the system **200** depicted in FIG. **2** is for discussion purposes only and should not be construed as limiting the claims in any way.

With reference now to FIGS. **3-6**, various strategies for dimming one or more illumination devices **100** will be described in accordance with at least some embodiments of the present disclosure. The various strategies may be implemented or enforced by an appropriately programmed or designed dimming control system **212** with control logic **216**. The legend for FIGS. **3-6** is depicted above FIG. **3** for ease of reference. The first set of light sources **232**a may correspond to "Set A" in FIGS. **3-6**, while the second set of light sources **232**b may correspond to "Set B." FIGS. **3-6** also show the resultant CCT output by the illumination device **100** or system **200** when implementing a dimming strategy.

Although each of the dimming strategies in FIGS. **3-6** will be described in connection with a decrease in current provided to the illumination device **100**, it should be appreciated that the logic in most cases can simply be reversed for dimming conditions where current provided to the illumination device **100** is being increased, but is still less than the maximum current (e.g., less than full brightness is desired).

It should also be appreciated that the control logic **216** may be programmed to implemented, one, some, or all of the dimming strategies disclosed herein. In other words, it is not necessary to limit the functionality of the control logic **216** to a single dimming strategy. Rather, the control logic **216** can be configured to implement many different dimming strategies and a user may be allowed to select which among the multiple dimming strategies should be implemented by the control logic **216** (e.g., via a selector mechanism or the like).

A first dimming strategy is depicted in FIG. **3** whereby a single transition condition is enforced. This first dimming strategy represents possibly the simplest dimming strategy, but may not necessarily result in the best continuity of CCT throughout the entire dimming operation. In particular, a single dimming threshold or predetermined input current may be set or defined within the control logic **216** as a transition condition. At the predetermined dimming point (e.g., when input current is a predetermined percentage of maximum input current), the control logic **216** will detect the reduction in input current has crossed the transition condition and the first set of light sources **232**a will be switched off in favor of the second set of light sources **232**b. In implementation, when the control logic **216** detects that dimming has reached the transition condition, the control logic **216** may generate and send two instructions. A first of the instructions may be sent to the first driver **228**a that causes the first driver **228**a to discontinue providing current to the first circuit **220**a. A second of the instructions may be sent to the second driver **228**b that causes the second driver **228**b to start providing current to the second circuit **220**b. It may be desirable to stage the order in which the first and second instructions are sent—specifically it may be desirable from a continuity of lighting perspective to send the first instruction prior to sending the second instruction.

Additionally, a certain amount of hysteresis may be built into the control logic **216** to prevent unwanted switching back and forth if the dimming instructions cause the input current to be at or about the transition condition. Specifically, the control logic **216** may not switch back and forth between states unless a predetermined amount of time has passed since a switch occurred.

As can be appreciated, the transition condition (predetermined ratio of maximum input current) may be set to any value between, but not including 0% and 100% of maximum input current. As one non-limiting example, the control logic **216** may implement a switch between the sets of light sources when input current is at a value of approximately 50% of maximum input current. As another non-limiting example, the transition condition may be programmed to occur when input current is at a value of 30% of maximum input current. It may also be desirable to determine at which point of dimming the first type of light source **116** in the first set of light sources **232**a begin to exhibit noticeable color shifting and the transition condition may be set to a value slightly above that point of dimming. Additionally or alternatively, the transition condition may be set based on the CCT of the first type of light source **116** and/or the second type of light source **120**.

FIG. **4** depicts another dimming strategy in accordance with at least some embodiments of the present disclosure. The dimming strategy depicted in FIG. **4** implements logic where the first set of light sources **232**a are not totally switched off at a transition condition, but rather are gradually dimmed in favor of the second set of light sources **232**b being gradually brightened, or vice versa. In particular, a mixing zone may be enforced to further smooth the resultant CCT shift of the illumination device **100** or illumination system **200**.

The mixing zone may itself correspond to an extended transition condition and the mixing zone may comprise an upper bound and a lower bound. The upper bound may correspond to a first point where the extended transition condition starts and the first set of light sources **232***a* begins to dim and/or the second set of light sources **232***b* begins to brighten. In some embodiments, the upper bound of the extended transition condition may at least correspond to a point where the second set of light sources **232***b* is turned on, perhaps at less than maximum input current for the second circuit **220***b*. The lower bound may correspond to a second point where the extended transition condition ends and the first set of light sources **232***a* are turned off and/or the second set of light sources **232***b* are operating at full current input.

It should be appreciated that the first set of light sources **232***a* does not necessarily have to be dimmed at the same rate as which the second set of light sources **232***b* are brightened. Specifically, the first set of light sources **232***a* may be dimmed faster than the rate at which the second set of light sources **232***b* are brightened or the first set of light sources **232***a* may be dimmed slower than the rate at which the second set of light sources **232***b* are brightened. As can be seen in FIG. **4**, the implementation of a mixing zone or extended transition condition may result in a smaller color shifting range while still providing an acceptable brightness dimming effect.

With reference now to FIG. **5**, yet another dimming strategy will be described in accordance with at least some embodiments of the present disclosure. The dimming strategy depicted in FIG. **5** shows a scenario where both the first and second sets of light sources **232***a*, **232***b* are lit (e.g., fully activated) at the same time and turned off (e.g., fully deactivated) at the same time. In this embodiment, the transition condition may still be an extended transition condition, but the extended transition condition may span the entire operating range of the sets of light sources **232***a*, **232***b*. This particular dimming strategy may have a slightly larger color shifting range as compared to the strategy depicted in FIG. **4**, but the resultant CCT of the illumination device **100** or system **200** during dimming may be relatively smoother. Again, although the first and second sets of light sources **232***a*, **232***b* are depicted as being dimmed at substantially the same rate, embodiments of the present disclosure are not so limited. Rather, the first set of light sources **232***a* may be dimmed faster than a rate at which the second set of light sources **232***b* are dimmed, or vice versa.

FIG. **6** depicts still another dimming strategy in accordance with at least some embodiments of the present disclosure. This particular dimming strategy the second set of light sources **232***b* comprises a lower CCT as compared to the first set of light sources **232***a*. The desired brightness transition can minimized color shifting can still be achieved with such a configuration if the number of light sources in the second set of light sources **232***b* is fewer than the number of light sources in the first set of light sources **232***a*. When a transition condition is detected and the second set of light sources **232***b* are activated, they may be activated by providing a maximum current to the second circuit **220***b*. However, since the number of light sources in the second set of light sources **232***b* is less than the number of light sources in the first set of light sources **232***a*, the overall brightness emitted by the illumination device **100** or system **200** can be lowered to demonstrate the desired brightness continuity.

FIG. **7** depicts an illustrative lighting control method in accordance with at least some embodiments of the present disclosure. The method depicted in FIG. **7** may correspond to or be used to implement any of the dimming strategies described above, alone or in combination.

The method begins by placing two or more sets of light sources, **232***a*, **232***b* for example, into a lighting system **200** (step **704**). Thereafter, the instructions being received at receiver **208** from remote control **204** may be monitored until dimming instructions are received (step **708**). It should be appreciated that dimming instructions may correspond to any input that indicates a desire to operate the illumination device **100** or system **200** at less than full brightness, with the overall brightness either decreasing or increasing.

The method continues with the control logic **216** monitoring the input for the occurrence of one or more transition conditions (step **712**). The detected transition condition may correspond to a single transition condition, a boundary of an extended transition condition, or a setting within an extended transition condition. If no transition condition is detected (step **716**), then the control logic **216** determines whether the dimming instructions are complete (step **720**). If dimming instructions are still being received at the receiver **208**, then the method returns to step **712**. Otherwise, the control logic **216** discontinues monitoring for a transition condition (step **728**).

Referring back to step **716**, if a transition condition has been detected, the control logic **216** determines the dimming strategy to implement and instructs one or more of the drivers **228***a*, **228***b* to implement the dimming strategy (step **724**). As noted above, the instructions provided to one or both drivers **228***a*, **228***b* may correspond to instructions to provide full current to the respective circuit, instructions to discontinue providing any current to the respective circuit, instructions to increase current provided to the respective circuit, and/or instructions to incrementally decrease current provided to the respective circuit. Thereafter, the method continues to step **720** to determine if dimming is complete.

Specific details were given in the description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits may be shown in block diagrams in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

While illustrative embodiments of the disclosure have been described in detail herein, it is to be understood that the inventive concepts may be otherwise variously embodied and employed, and that the appended claims are intended to be construed to include such variations, except as limited by the prior art.

What is claimed is:

1. A dimmable illumination device, comprising:

a first set of light sources being driven by a first circuit driver;

a second set of light sources being driven by a second circuit driver; and

a dimming control system including dimming control logic, the dimming control logic being configured to provide driving instructions to the first circuit driver and the second circuit driver, wherein the dimming control logic is programmed to monitor a dimming input signal for the illumination device and determine that the dimming input signal has reached a transition condition such that the first set of light sources is to be enhanced by the second set of light sources, wherein the transition condition is an extended transition condition comprising an upper bound and a lower bound, wherein the driving instructions cause both the first and second set of light sources to be fully activated at the same time and fully deactivated at the same time, and wherein the extended transition condition spans an entire operating range of both the first and second set of light sources.

2. The device of claim **1**, further comprising:

a receiver configured to receive the dimming input signal from a remote control and provide the dimming input signal to the dimming control system.

3. The device of claim **2**, wherein the receiver communicates with the remote control wirelessly.

4. The device of claim **1**, wherein the upper bound corresponds to a point at which the dimming control logic instructs the first circuit driver to begin reducing current provided to the first set of light sources, the lower bound corresponding to a point at which the dimming control logic instructs the first circuit driver to stop providing current to the first set of light sources.

5. The device of claim **1**, wherein the transition condition corresponds to a predetermined percentage of maximum brightness.

6. The device of claim **5**, wherein the dimming control logic is programmed with hysteresis to prevent activating and deactivating the first set of light sources within a predetermined amount of time.

7. The device of claim **1**, wherein at least one of the first and second sets of light sources is dimmable.

8. The device of claim **1**, wherein the first set of light sources comprises a first Correlated Color Temperature (CCT), wherein the second set of light sources comprises a second CCT, and wherein the first CCT is lower than the second CCT.

9. The device of claim **1**, wherein at least one of the first set of light sources and the second set of light sources comprises at least one of a Light Emitting Diode (LED), an array of LEDs, and an Organic LED (OLED) sheet.

10. The device of claim **1**, wherein the first set of light sources comprises a different number of light sources as compared to the second set of light sources.

11. The device of claim **1**, wherein the control logic comprises at least one of an Application Specific Integrated Circuit (ASIC), firmware, and a Programmable Logic Circuit (PLC).

12. The device of claim **1**, wherein the dimming control logic causes the first set of light sources to be enhanced by the second set of light sources in response to determining that the dimming input signal has reached the transition condition.

13. The device of claim **1**, wherein the dimming control logic causes the first set of light sources to be replaced by the second set of light sources in response to determining that the dimming input signal has reached the transition condition.

14. The device of claim **1**, wherein the dimming control logic instructs the first circuit driver to decrease current provided to the first set of light sources in response to determining that the dimming input signal has reached the extended transition condition.

15. The device of claim **14**, wherein the dimming control logic instructs the first circuit driver to decrease the current provided to the first set of light sources before instructing the second circuit driver to increase the current provided to the second set of light sources.

16. The device of claim **1**, wherein the dimming control logic instructs the first circuit driver to cease providing current to the first set of light sources at substantially the same time that the dimming control logic circuit instructs the second circuit driver to cease providing current to the second set of light sources.

17. A dimmable illumination device, comprising:

a first light source;

a second light source; and

a dimming control system including dimming control logic, the dimming control logic being configured to provide driving instructions to at least one circuit driver that drives the first and/or second light source, wherein the dimming control logic is programmed to monitor a dimming input signal for the illumination device and determine that the dimming input signal has reached a transition condition such that the first light source is to be enhanced by the second light source, wherein the transition condition is an extended transition condition comprising an upper bound and a lower bound, wherein the driving instructions cause both the first and second set of light sources to be fully activated at the same time and fully deactivated at the same time, and wherein the extended transition condition spans an entire operating range of both the first and second set of light sources.

18. The device of claim **17**, wherein the upper bound corresponding to a point at which the dimming control logic instructs the at least one circuit driver to begin reducing current provided to the first light source.

19. The device of claim **17**, wherein the first light source comprises a first Correlated Color Temperature (CCT), wherein the second light source comprises a second CCT, and wherein the first CCT is lower than the second CCT.

20. The device of claim **17**, wherein the transition condition corresponds to a predetermined percentage of maximum brightness and wherein the dimming control logic is programmed with hysteresis to prevent activating and deactivating the first light source within a predetermined amount of time.

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